# WIDEBAND RECONFIGURABLE PRINTED DIPOLE ANTENNA WITH HARMONIC TRAP


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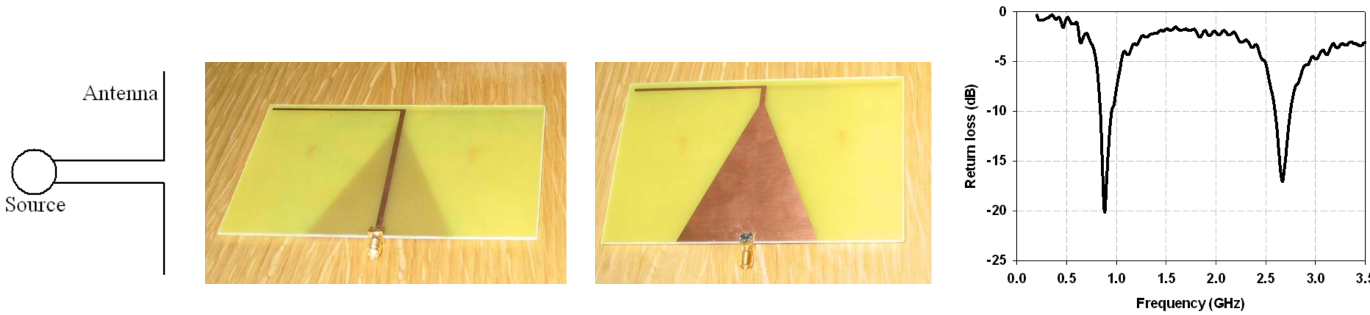
## INTRODUCTION

Reconfigurable antennas have received a great deal of attention for their applications in wireless communications in recent years. They can be used for changing the operation frequency [1]-[6] or changing the radiation pattern [7]-[9]. In [1] a reconfigurable microstrip antenna was designed by placing MEMS series switches at the radiating edge. The series switches connect extra sections of transmission line to the microstrip antenna, thereby lowering its resonant frequency. In [2] a micromachined membrane was used as the ground plane below the microstrip patch antenna to design a frequency-agile patch antenna. In [3] a square patch antenna with switchable slots was proposed for dual band circular polarization operation. A dual band dipole using series MEMS switches was presented in [4] and a dual band reconfigurable Yagi antenna in [5]. A single-fed resonant slot, loaded with a series of PIN diodes switches, was designed in [6]. In [7] it was shown that by using RF switches the radiation pattern of the Hilbert curve fractal antenna could be made adaptively reconfigurable and also resonance frequency of the antenna was tunable by using the switches. In [8] a beam-switched Rhombic antenna was proposed. In [9] a reconfigurable single turn square microstrip spiral antenna was presented which can be reconfigurable in radiation pattern and frequency.

This paper introduces a reconfigurable printed dipole antenna to select one of several frequency bands, which cover a wide frequency range. Due to wideband coverage of these frequency bands, selecting only one of the frequency bands at each time can make difficulties, if the higher order modes are taken into account. In fact, when the antenna operates at lower frequency bands the higher order modes can be matched at higher frequencies and this is not desired. To eliminate the higher order modes the use of a harmonic trap is proposed in this paper. It is experimentally shown that by using switches and harmonic traps, a reconfigurable printed dipole antenna can be designed to select several frequency bands, which cover a wide frequency range.

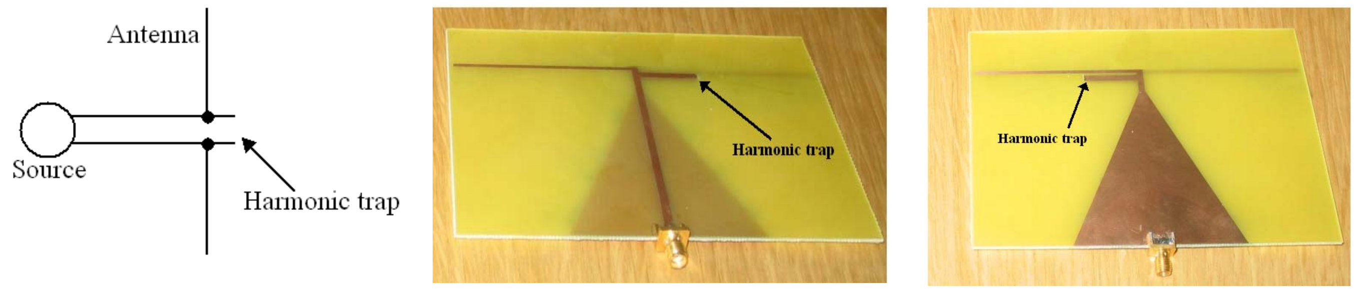
## HARMONIC TRAP

In this section higher order modes elimination by using harmonic trap is explained. Fig. 1 shows the top and backside of a printed dipole antenna and its schematic. The antenna is fed by a tapered balun, which is a transition between a 50Ω microstrip line to a 72Ω parallel strip transmission line connected to the antenna. The tapered ground has a length of 64mm and a maximum width of 64mm at the beginning of microstrip line and the minimum width of 3mm at the parallel strip lines. The width of the microstrip line is 3mm. The length of each dipole arm is 64mm and its width is 1.5mm. The antenna is printed on the both sides of a 1.6mm thick FR4 substrate with the permittivity of 4.5 and fed through a 50Ω SMA connector. Fig. 1d shows its measured return loss. As it can be seen, the antenna has a good matching at the fundamental mode, 900MHz, and the third harmonic, 2.7GHz. To eliminate the third harmonic an open circuit stub with the length of $\frac{\lambda}{4}$ at the frequency of $3f_0$ can be used. Fig. 2 shows the antenna with the harmonic trap and its schematic to eliminate the third harmonic. The length of the open circuit stub is 21mm. Fig. 3 shows the measured return loss of the printed dipole antenna with harmonic trap. To make a comparison the measured return loss of the printed dipole without harmonic trap is also shown in Fig. 3. As it depicted in Fig. 3 the third harmonic has been eliminated. In fact, the open circuit stub at the frequency of $3f_0$ shorts the antenna.




(a) (b) (c) (d)

**Fig. 1- printed dipole antenna, a) schematic, b) topside, c) backside, d) measured return loss**




(a) (b) (c)

**Fig. 2- printed dipole antenna with harmonic trap, a) schematic, b) topside, c) backside**

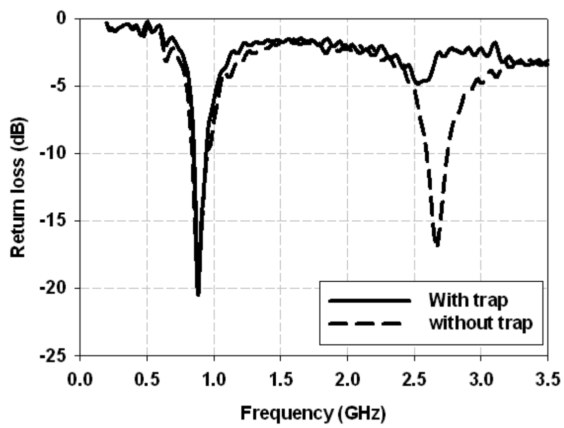



**Fig. 3- measured return loss of the printed dipole with and without harmonic trap**

## RECONFIGURABLE PRINTED DIPOLE ANTENNA DESIGN

A reconfigurable printed dipole antenna was designed and fabricated based on the concept of the harmonic trap. All of the dimensions are the same as the printed dipole antenna discussed in the previous section. The switches were assumed ideal and the open and closed states of the switches were modelled with the absence or presence of a metal pad whose area is $1mm \times 1.5mm$. The antenna is designed to select one of the seven frequency bands, so it needs six switches on each dipole arm. In order to fabricate the reconfigurable antenna six metal pads are placed on each dipole arm so that seven dipoles with the lengths of 128mm, 110mm, 90mm, 74mm, 60mm, 50mm and 38mm can be obtained by removing the metal pads (one metal pad for the second band, two metal pads for the third band,… and six metal pads should be removed for the seventh band). A metal pad is also considered to switch the length of the trap from 21mm for the lowest band to 18mm for the second band. The overall operation frequency band is from 800MHz to 3 GHz in this paper and the third harmonic of the third frequency band and higher bands are at the higher than 3GHz which is above the overall operation band. So for the third and higher bands the harmonic trap can be switched off. However for a wider overall frequency band, where the higher order harmonics fall inside the overall band, more switches are needed

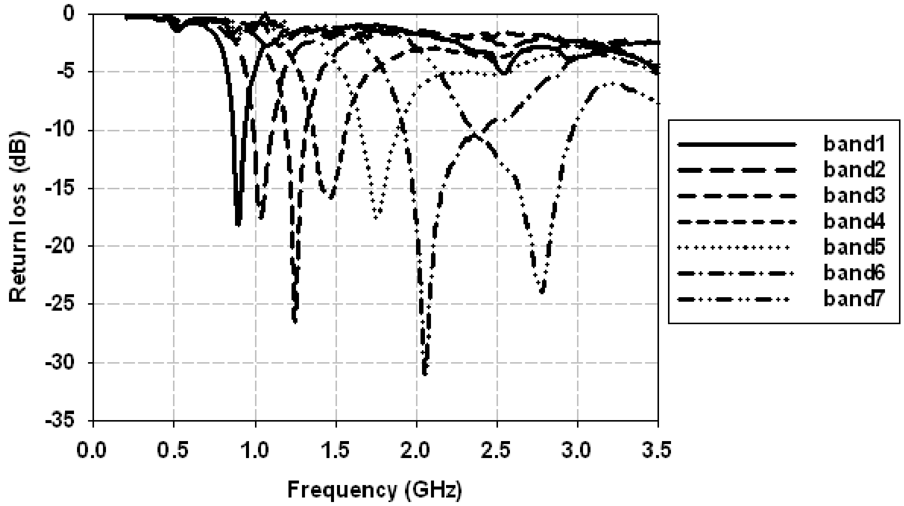
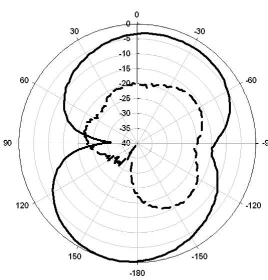



**Fig. 4- measured return losses of the reconfigurable printed dipole for selecting seven frequency bands**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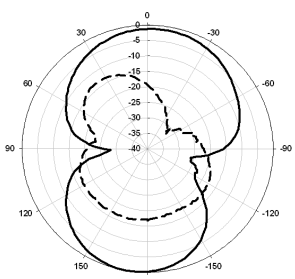
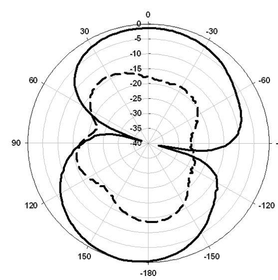
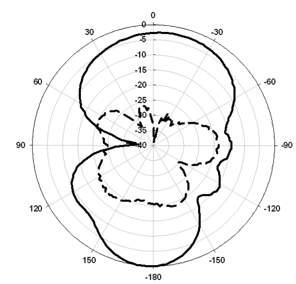
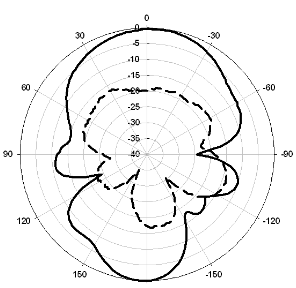
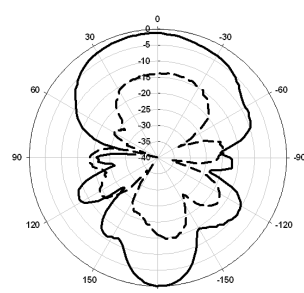

1050 MHz


1205MHz


1460 MHz


1750 MHz


2050 MHz

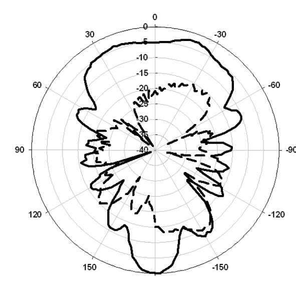

2770MHz

**Fig. 5-measured radiation patterns of reconfigurable printed dipole at the resonance frequency of the bands in E-plane, solid line is co-polarization and dashed line is cross-polarization.**

to shorten the harmonic trap. Fig. 4 shows the measured return loss of the reconfigurable printed dipole antenna with harmonic trap. It can be observed that the third harmonic of the lower bands, such as the first and second band, are eliminated by using harmonic trap, so in this case the antenna selects only one of the frequency bands each time.

The radiation patterns of the antenna were measured at the resonance frequencies of the selectable frequency bands. Fig. 5a shows the measured radiation patterns in E-plane for the first, third, fifth and the seventh band and Fig. 5b shows the patterns in H-plane. As it can be seen from the Fig. 5, nulls occur at the higher frequency bands especially at the seventh band in E-plane. This degradation is believed to be due to the tapered ground plane. The tapered ground plane acts as a reflector and can degrade the radiation pattern. It is worse for the higher frequency bands where the tapered ground size is larger in comparison with operating wavelength.

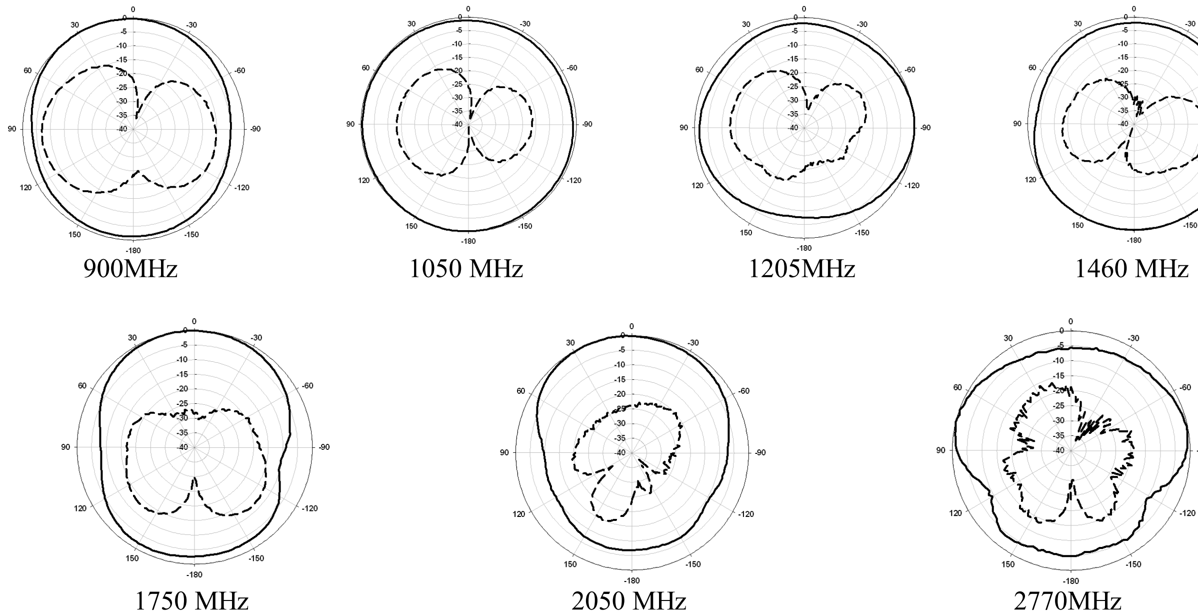



**Fig. 6- measured radiation patterns of reconfigurable printed dipole at the resonance frequency of the bands in H-plane, solid line is co-polarization and dashed line is cross-polarization.**

## CONCLUSION

The concept of using harmonic trap to eliminate higher order modes in reconfigurable frequency band antennas is proposed. A reconfigurable printed dipole antenna with harmonic trap to select seven frequency bands covering 3:1 overall operation bandwidth was designed, fabricated and measured. The results show that the fabricated antenna with harmonic trap can select one of the lower frequency bands without selecting the higher frequency bands by eliminating higher order modes.

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